

MRCP and MRI in the Evaluation of Bile Duct Obstruction

Caroline Reinhold, M.D., M.Sc.
Professor, Departments of Radiology, Gynecology & Gastroenterology
Director, MR Imaging
Director of Research
McGill University Health Centre, Montreal, Quebec
Medical Director, Oncology
Synarc Inc., San Francisco

Sharad Maheshwari, M.D.
Fellow, Department of Radiology
McGill University Health Centre, Montreal, Quebec

Send Correspondence to:

Caroline Reinhold, M.D.
Department of Radiology
McGill University Health Centre
Montreal General Hospital Site
1650 Cedar Avenue
Montreal, QC H3G 1A4
Canada

Tel: (514) 934-1934 ext: 42872
Fax: (514) 934-8263
E-mail: caroline.reinhold@muhc.mcgill.ca

Introduction

Magnetic resonance cholangiopancreatography (MRCP) uses heavily T2-weighted sequences to non-invasively image the biliary tree and pancreatic duct. MRCP is a noninvasive procedure without risks, as compared to ERCP. The rate of complications secondary to ERCP, range from 5 to 8%, with an overall mortality rate of up to 1.5%.¹⁻² MRCP is superior in visualizing the bile ducts proximal to a site of obstruction,³ and can provide additional information on extraductal parenchymal abnormalities, vascular structures, lymph nodes and distant metastases.^{4,5} Drawbacks of MRCP include an inferior spatial resolution relative to ERCP, limited evaluation of the ampulla, non-distension of the biliary system, and no biopsy or treatment capability.

MRCP Techniques and Imaging Protocols

The patient is required to fast for a minimum of three to four hours prior to the examination to allow gallbladder filling, gastric emptying, and to reduce unwanted secretions and fluid signal from the intestine. An oral contrast agent that shortens the T2 relaxation time of bile, such as iron oxide agent, may be ingested to suppress the signal from fluid within the gastrointestinal tract. In addition, an antispasmodic agent (glucagon 1 mg I.V. or I.M.; or hyoscine butyl bromide 40 mg I.M.) may be administered at the onset of the examination.

Most anatomic imaging methods for MRCP rely on the principle that only stationary fluids (such as bile) will be visible on strongly T2-weighted images, with background signal suppression.^{6,7} For this purpose, MRCP is usually obtained with a heavily T2-weighted sequence using a single-shot fast spin-echo technique (SSFSE, HASTE), and both a thick-collimation (single-section / SLAB) and thin-collimation (multisection) approach with a body phased-array coil. The echo time used is long, typically on the order of 1000 millisecond for a SLAB and approximately 180 msec for a multi-slice acquisition. If a thick (e.g. 40 mm) slice is acquired, then a large portion of the biliary system is displayed in a single image, and there is complete background suppression. In a multi-slice acquisition ($TE \leq 180$), there is less background signal suppression and the biliary tree can be visualized in relation to the abdominal organs. A SSFSE, using a short inter-echo spacing, minimizes susceptibility artifacts from metallic surgical clips, vascular stents and surgical drainage catheters.⁸ Alternatively, a respiratory-gated 2D fast spin-echo, or a breath-hold or respiratory-gated 3D sequence, like Fast Recovery Fast Spin Echo (FRFSE), enables the acquisition of thinner slices thereby permitting a maximum intensity projection that can be rotated. To avoid partial volume effect, thin-slice source images need to be carefully assessed for each patient.⁹

Conventional MR imaging with non-enhanced T1 and less heavily T2-weighted images provide added value for the diagnostic accuracy in differentiating benign from malignant causes of biliary dilatation. Administration of a gadolinium chelate (0.1 mmol/kg given IV at 2 cc/second) is helpful for evaluation of suspected neoplasm and infection. Images are acquired pre-contrast, as well as in the arterial (~20 second) portal (~50 second), and systemic (~2 minutes) post contrast phases using a fat-suppressed 3D sequence (eg VIBE, FAME, LAVA). Typical pulse sequences and imaging parameters for MRCP are provided in Table 1.

Table 1. Typical imaging parameters for various MRCP acquisitions.

	<u>Localizer</u>	SSFSE	SSFSE	MRCP (Thick slice)	FRFSE 3D	2D FSE	3D T1 (pre/ post-gad)
Plane Mode Pulse Seq. Imaging Opt.	3 Plane	Coronal 2D SSFSE Fast	Transverse 2D SSFSE Fast	Oblique, multiple orientations 2D SSFSE Fast	Coronal 3D FRFSE Fast	Transverse 2D FSE	Transverse 3D SPGR ZIPx2, ZIP512
# of Echoes TE TR Optional Flip Angle BW Saturation		180 3000 (resp.trig./ ASSET) --- 62	180 3000 (resp.trig./ ASSET) --- 62	1 second 3000 --- 50	1 500-600 ~4000 (resp. trig.) ---- 31 Fat	31 150-250 ~4000 (resp. trig.) ---- 31 Fat	1 In-phase Min 12 62 Fat, special
FOV Slice thickness (mm) Spacing (mm) Matrix NEX	40 8 2 256x128 1	32-40 4-5 mm 0 384x224 0.5	32-40 4-5 mm 0 384x224 0.5	28-38 40 mm --- 320x320 1	32-40 1.6 mm (zip2 & zip512) 256x256 1	32-40 3 mm 0.3 384x256 2	32-40 3-4 mm 0 256x192 0.75

Functional MR Cholangiography (fMRC)

Functional MR cholangiography (fMRC) involves the administration of a hepatobiliary contrast agent, like manganese dipyradoxal diphosphate.¹⁰ These agents are lipophylic, and are taken up by hepatocytes and excreted into the biliary ductal system. They lead to bright signal of contrast-enhanced bile on T1-weighted images, using 2D or 3D T1-weighted gradient echo techniques.

Kinematic MRCP

Kinematic MRCP can be used to assess the sphincteric segment of the ampulla of Vater.¹¹ By using this technique pathologic stenosis may be distinguished from non-visualization of the sphincteric segment caused by physiologic contraction of the sphincter of Vater. It is performed by acquiring a series of thick-slice (20 mm) SSFSE images in an optimal plane for the visualization of the sphincteric segment and then displaying them as a cine loop.¹²

Bile Duct Obstruction

The presence of bile duct obstruction is diagnosed on MRCP when the maximal diameter of the extrahepatic bile duct exceeds 7 mm in patients who have their gallbladder in place and 10 mm in patients who have undergone a cholecystectomy. IHBD dilatation can be suspected if the maximal caliber of the central IHBD exceeds 2-3 mm.¹³ Benign stenoses tend to have smooth borders with tapered margins, whereas malignant lesions usually manifest as irregular strictures with shouldered margins with or without an associated mass. Conventional T1 and T2-weighted images allow exclusion of associated soft tissue masses, lymphadenopathy or pancreatic head masses. In a recently published meta-analysis MRCP achieved 95% sensitivity, and 97% specificity for identifying the presence and level of bile duct obstruction.¹⁴

Causes of Bile Duct Obstruction

Cholelithiasis

Biliary obstruction is caused by common duct stones in 20-42% of cases.¹⁵ The reported sensitivity and specificity of MRCP for diagnosing CBD stones in a recently published meta-analysis is 92% and 97%, respectively.¹⁴ However, the ability of MRCP to diagnose small stones in non-dilated ducts appears to be more limited^{16,17} when image quality is optimal, calculi as small as 2 mm can be detected in dilated and non-dilated ducts.

Data available on the accuracy of MRCP in the diagnosis of intrahepatic stones is more limited. However, in a recently published study, MRCP achieved a sensitivity and specificity of 97% and 93%, respectively, while ERCP achieved a sensitivity, and specificity of 59% and 97%, respectively.¹⁸

For accurate diagnosis it is important to scrutinize the thin section source images, since reconstruction techniques may mask small stones. Bile duct stones may be completely surrounded by fluid and can be missed due to volume averaging effects, especially when thick section imaging is performed. The differential diagnosis for filling defects in the bile ducts include: biliary stones, neoplasms, blood clots, concentrated bile, flow voids, metallic stents, susceptibility artifacts from surgical clips, and air bubbles. The latter can be differentiated from calculi by demonstrating an air-fluid level on transverse or sagittal images and a filling defect in the nondependent portion of the bile duct.¹⁹

Ampullary Stenosis / Ampullary Fibrosis

Ampullary stenosis and ampullary fibrosis is commonly caused by surrounding inflammatory changes secondary to the passage of stones in the context of choledocholithiasis. MR imaging findings in the acute phase when the ampulla is swollen and edematous include 1) bile duct obstruction; 2) enlargement of the ampulla; and 3) increased signal intensity of the ampulla on T2-weighted images. Once these changes become chronic, the ampulla returns to its normal size and appears of low signal intensity on T2-weighted images due to progressive fibrosis.

Sphincter of Oddi Dysfunction

Sphincter of Oddi dysfunction includes spasm of the sphincter of Oddi and abnormalities of the rate of sphincteric contraction causing functional stenosis.²⁰ Non-visualization of the sphincteric segment on routine MRCP can be a normal finding. MRCP is useful to establish the diagnosis of sphincter of Oddi dysfunction by excluding other causes of distal bile duct obstruction. The morphology and contractility of the sphincter of Oddi may be examined by the acquisition of kinematic MRCP images.¹²

Primary Sclerosing Cholangitis

Primary sclerosing cholangitis (PSC) is an idiopathic, chronic, fibrosing, inflammatory disease of the bile ducts of unknown etiology. Up to 70% of patients will have inflammatory bowel disease. MRCP may be negative in the early stages of PSC. In patients with more advanced disease, MRCP depicts the intrahepatic bile ducts better than ERCP (69% versus 52%) and can depict more strictures especially of the peripheral intrahepatic ducts.²¹⁻²⁵ Conversely, MRCP may over- or underestimate the extent of a stricture of the extrahepatic duct, especially in the setting of multiple strictures where the duct downstream from a stricture may be collapsed.^{21, 23, 24}

The most common findings – in order of decreasing frequency – on MR imaging in patients with PSC include: intrahepatic bile duct dilatation (77%); enhancement of the extrahepatic bile duct wall (67%); intrahepatic bile duct strictures (64%); extrahepatic bile duct wall thickening (50%) and stenosis (50%); and intrahepatic bile duct beading (36%).²⁶ The key MRCP feature of PSC is the characteristic beaded appearance produced by randomly distributed short annular strictures alternating with slightly dilated segments. These strictures are usually located at the bifurcation and are out of proportion to upstream ductal dilatation. When peripheral ducts become obliterated they are not visualized to the periphery of the liver and thus produce a pruned-tree appearance. Intrahepatic bile duct dilatation occurs in about 80% of patients and is considered present if the intrahepatic ducts have a greater diameter than the more central ducts, or if they measure more than 3 mm.²⁵⁻²⁶

One of the most significant complications of PSC is the development of cholangiocarcinoma, which occurs in 10 to 15% of patients.^{27,25} There are several cholangiographic findings that suggest the presence of a superimposed cholangiocarcinoma, such as rapid progression of strictures; high-grade irregular ductal narrowing with shouldering; marked dilatation of ducts proximal to strictures and; the development of polypoid or mass lesions. The MR imaging findings of cholangiocarcinoma are discussed in greater detail below.

Cholangiocarcinoma

Cholangiocarcinomas can be classified based on their location as peripheral intrahepatic, hilar intrahepatic, and extrahepatic, and are distinct disease entities clinically, therapeutically and radiologically. MRCP has a high accuracy for predicting the Bismuth grade of biliary ductal involvement.²⁸ MRCP provides a complete map of the biliary tree anatomy and a three-dimensional overview with imaging capability on both sides of the stricture. Complete tumor staging and assessment of liver involvement, portal nodes, portal veins, and/or hepatic arteries can be obtained from additional MR pulse sequences including fat suppressed contrast-enhanced T1-weighted gradient echo sequences.⁷

Hilar cholangiocarcinoma accounts for more than 50% of all large bile duct malignancies.²⁹ These tumors are usually small at diagnosis since they typically present early with biliary obstruction, jaundice or cholangitis. The most common type of hilar cholangiocarcinoma (Klatskin tumor) is an infiltrating cholangiocarcinoma in 70% of cases. On MRCP, hilar cholangiocarcinoma appears as a moderately irregular thickening of the bile duct wall (3-5 mm), with dilation of the intrahepatic bile ducts.³⁰ High-grade obstruction disproportionate to the degree of duct wall thickening may be a feature of cholangiocarcinoma. On MR imaging, the lesion appears hypointense on T1-weighted images and has moderately high-signal intensity on T2-weighted images. Hilar cholangiocarcinomas do not show any typical enhancement pattern. However, these are typically hypovascular tumors compared with the adjacent liver parenchyma and show a heterogeneous enhancement that peaks on delayed images.³¹ This pattern is consistent with the fibrous nature of the tumor. Increased intrahepatic duct wall enhancement has been observed proximal to the tumor, however, as an isolated finding may not be a predictor of tumor involvement. The increased enhancement of the duct wall may be due to fibrosis, or inflammation resulting from obstruction. Additional MR imaging findings include segmental / lobar atrophy of the liver secondary to portal vein invasion, or secondary to right or left ductal obstruction.

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